Vol. XLI. JUNE, 1899.

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INSTITUTED 1852.

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Practice of Foreign Governments.—The practice of foreign governments differs widely from this. In Europe, not only national graving docks, but all great modern works of this kind are constructed of stone or concrete masonry. Thus, the British Government owns or

controls sixty-two graving docks—some of which are locks, which answer the purposes of dry docks—and only one of these is of timber, that at St. John's, Newfoundland, which was built by the Colonial Government. France has thirty-six, Germany has eleven, and Italy has twelve, graving docks, all of which, in the three countries, are of masonry. In Germany, a large dry dock was recently designed for a corporation there, which was to be subsidized by the Government. When, however, the dock company proposed to use timber as the material, the Government declined to aid, and it was only upon condition that the dock be of masonry that the subsidy was finally granted. Mr. Cathcart.

It will be seen, then, that the United States Government is the only one in the world which has constructed, directly, a timber dry dock. The governments of Europe have considered it the policy of wisdom to build these important works of the most enduring materials, without regard to cost. This decision has been reached, doubtless, in view, not only of the natural decay, the frequent repairs and the large expense thereof, to timber dry docks, but, as well, because of the superior stability, permanence and safety of a dock which is built of stone or concrete.

Timber vs. *Stone in Dry Dock Construction, with Regard to Deterioration.*—Timber dry docks are subject to decay, especially in the upper portions of the works, which are alternately wet and dry. The deterioration is especially swift in a warm, moist climate; but, even in northern latitudes, where decay is much slower, docks built of wood require, in about 25 years, very extensive renewals. In southern waters, submerged timber, also, perishes rapidly from the attacks of the teredo.

On the other hand, the masonry dock, if built of granite or other enduring stone and mortar of the best Portland cement, is a permanent work. In the older stone dry docks of the United States, where the mortar was made with native hydraulic cements, the masonry has suffered some injury to the joints of the entrance works, from which there was resultant leakage. This has occurred to a small extent, with the docks at Boston and Norfolk; but there has been no serious dislocation of the masonry, and the small amount of leakage has injured the structure in no way and has involved little expense for renewal. These two docks, although sixty-five years old, have had inconsiderable repairs to the masonry. The same action, from the same cause, took place with the stone dock at the Brooklyn Navy Yard. In this case, owing to the strong pressure from springs upon the site, the disintegration of joints by frost was considerable, and there was heavy leakage. Repairs, made in the best manner, were, however, wholly effectual. As a general principle, it may be broadly stated that it is possible to make a masonry dry dock absolutely water tight.

Mr. Cathcart. *Cost of Maintenance of the Various Stone and Timber Dry Docks of the United States Navy.*—The relative values of stone and timber in dry-dock construction may be considered, first, with regard to the cost of maintenance of the docks, and, secondly, with regard to their stability and safety. The first consideration only will be discussed herein.

As to this maintenance, it is obvious that the proper basis of comparison is the relative costs of repairs to the structures proper, not including the accessories, such as pumping plant, caisson, floating gates, etc., inasmuch as the cost of maintenance of the latter should be the same in all similar docks, without regard to the material of construction of the dock proper. The history of the national dry docks of the United States is instructive in this respect.

Stone Dry Dock at the Navy Yard, Boston.—This dock was completed in March, 1834. The record of its repair and maintenance prior to 1866 is incomplete and not readily accessible. From that time, however, to September 1st, 1897, a period of 31 years, the expenditures for these items were as follows:

Repair and maintenance of dock proper.....		$62 000
Pumping plant.....	$53 764	
Caisson and swinging gate.....	14 899	
		68 663
Total.....		$130 663
Average, for dry dock proper, per year.....		2 000

It will be observed that less than half of the total amount, or 47%, was expended upon the dry dock proper.

Stone Dry Dock at Norfolk, Va.—This dock was built of cut granite, upon the same plans as the dock at Boston. The early records as to its maintenance are not available. From 1882 to 1897, a period of 15 years, the expenditures were as follows:

Repair and maintenance of dock proper.....		$18 776
Pumping plant.....	$12 108	
Caissons or floating gates.....	30 546	
		42 654
Total.....		$61 430
Average, for dry dock proper, per year.....		1 251

It will be noted that the expenditures upon the dock proper are but 30% of the total.

Stone Dry Dock at Brooklyn, N. Y.—This dock was completed in 1851. The figures for this dock do not compare favorably with those already given, owing to the character of the soil in which it was con-

structed and to the quality of the cement used in the joints. Many difficulties were encountered with the foundations, arising from the large springs upon the site, which were never driven entirely from the locality. The stratum through which the springs flowed was 30 ft. below the foundations. As the water was entirely fresh, as its volume was not affected by the rise and fall of the tides, and as the temperature differed from that of the water in the bay, it is unquestionable that the flow came from a source much higher than tide-water. Mr. Cathcart.

Again, the mortar used in the construction of this dock was not made from the fine Portland cement manufactured at the present day, but from the hydraulic cements which were used in all structures of its type at the time of its building.

The heavy pressure from the springs referred to, combined with the inferior quality of the cement, and the action of frost, tended to produce disintegration of the masonry, to some extent, with, in consequence, very considerable leakage, thus necessitating during the fiscal years 1886–87 and 1887–88, extensive repairs, amounting to about $88 000. It became essential to take up and relay most of the masonry at the entrance and a small portion at the head. The repairs, made with great care, and with the best Portland cements, were wholly successful, and, during the 10 years which have passed since their completion, there have been no signs of failure of the masonry, to any extent.

Despite these adverse conditions, the total cost of repairs and maintenance of the dock proper, for 45 years ending with 1897, has been but $210 618, or an average of $4 680 per year. The cost of repairs to the caisson, gates, etc., during the same period, was $69 762. The cost of maintenance of the pumping plant during this time is not available.

Stone Dry Dock at Mare Island, Cal.—This dock was completed in 1891. Since that time, up to, and including 1897, the expenditures have been as follows:

Repair and maintenance of dock proper		$1 613
Pumping plant	$8 258	
Caisson or floating gate	4 534	
		12 792
Total		$14 405

Average, for dry dock proper, per year, during this period of 7 years $230

The expenditures upon the dock proper were, in this case, but 11% of the total. It will be observed that the figures given do not include the cost of a 40-ton crane and track, and of a spare caisson which was

Mr. Cathcart. provided as a relief in case of repairs to the original. In some published comparisons, to be later referred to, a large proportion of these items would seem to have been charged erroneously against repairs to the dry dock proper.

Similar expenditures upon the wooden dry docks of the Navy will now be considered.

Timber Dry Dock No. 2, Navy Yard, N. Y.—This dock was completed in 1890. The expenditures upon it for the first 7 years of its life were as follows:

Repair and maintenance of dock proper		$1 982
Pumping plant.....	$3 086	
Caisson, gates, etc.....	12 706	
		15 792
Total		$17 774

This would give, during this period, an average cost of repairs per year, to the dock proper, of but $283; but the story does not end here. The timber work of this dock has deteriorated considerably, and an inward movement of the abutments has taken place. The dock, in consequence of these defects, was surveyed by a board of civil engineers in 1898, and its condition was such that they recommended an entire remodeling and reconstruction of the entrance in concrete instead of timber. At its last session, Congress appropriated the sum of $300 000 for making these repairs.

If this work be completed in the year 1900, the dock will have cost, for repairs and maintenance, during the first 10 years of its life, $317 774; and, for the dry dock structure proper, $301 982; or an average of $30 198 per year.

It is quite true that this large sum for repairs in concrete is much more than would be the cost of the work in timber; and yet the Navy Department has considered the expenditure necessary in order to make the dock wholly trustworthy.

Timber Dry Dock at the Navy Yard, League Island.—This dock was completed in 1891. During its first 6 years of life, the expenditures upon it were as follows:

Repair and maintenance of dock proper.....		$10 202
Pumping plant.....	$3 632	
Caisson	113	
		3 745
Total.....		$13 947
Average, for dry dock proper, per year.....		$1 700

Mr. Cathcart.

The upper portion of the timber work, however, has decayed, to a very great extent, and there has been an inward movement of the abutments which has threatened an increase sufficient to prevent the seating of the caisson in its groove. In view of these facts, Congress, at its last session, appropriated $64 000 for repairs. If these repairs be completed during the present year, the dock will have cost, within the first 9 years of its life, $77 947; and the repairs and maintenance of the structure proper, $74 202, an average of $8 245 per year.

Timber Dry Dock No. 3, Navy Yard, N. Y.—This dock was completed in the spring of 1897. In the 2 years of its existence, it has cost $171 000 for repairs, an average of $85 500 per year.

These extraordinary expenditures, it is but just to say, resulted from a failure of the dock, due to faults in the construction, not in the design. If the work had been faithfully carried out, the injuries would not have occurred, and the expenditures for repairs, during these 2 years, would probably have been merely nominal. On the other hand, the failure was of a character which could not have occurred in a masonry or concrete dock.

Timber Dry Dock, Navy Yard, Norfolk, Va.—This dock was completed in 1889. The expenditures upon it to June, 1897, or during the first 8 years of its existence, were as follows:

Repair and maintenance of dock proper		$13 576
Pumping plant	$8 312	
Caisson or floating gate	1 532	
		9 844
Total		$23 420
Average, for dry dock proper, per year		$1 697

Since the date given above, however, Congress has made two appropriations for repairs to the structure, aggregating $35 000. These will have been expended within a few months, making the total cost for repairs to the dry dock structure proper during its 10 years of life $48 576, an average of $4 857 per year.

Timber Dry Dock at Port Royal, S. C.—This dock was completed in 1895. For the first 2 years the repairs upon the dry dock structure proper amounted to $4 262, an average of $2 131 per year.

Since this period, however, about $12 000 have been expended in repairs to the structure, making for 4 years a total of $16 262, or an average of $4 065 per year.

In summing up, finally, the relative cost of maintenance of the stone and wooden docks of the navy, the stone docks at Boston, Norfolk and Mare Island will be considered and that at New York omitted, because, from the character of its foundations and the cement used originally in its construction, it is not fairly representative.

Mr. Cathcart. From the wooden docks there will be omitted also Timber Dry Dock No. 3, at New York, the large expenditures for which are due to faults in building; but the timber docks at New York, League Island, Norfolk and Port Royal will be included (see Table No. 1).

It will be seen that the dates previously set forth herein, cover for the three stone docks, an average period of 17⅔ years, and for the four timber docks an average period of but 8¼ years, which period is, however, as long as the age of the latter permits. The total expenditure on the structures proper has been, for the three stone docks, $82 389, or an average of $27 463 per dock during the average period of 17⅔ years. The corresponding cost of the four timber docks has been $441 022, or an average of $110 255 per dock during their average life of 8¼ years. The average per dock structure proper per year on the basis of the figures given above is, for the stone docks, $1 558; for those of timber, $13 364, or more than eight and one-half times as much. Results such as these would seem to make most questionable the further use of timber in the building of national docks.

Disregarding, however, all comparisons, the fact remains that the four timber docks referred to have cost in repairs to the structures proper during an average life of 8¼ years in expenditures and sums appropriated the large amount of $441 022. As has been said, the failure of Timber Dry Dock No. 3, at New York, was of a character which could not have occurred in a masonry or concrete dock. There is ground, therefore, for adding the cost of repairs upon its structure to the above amount, which will give a grand total of $612 022 expended in repairs, during a comparatively brief period, to the timber docks proper of the navy.

Published Comparisons of the Cost of Maintenance of Stone and Timber Dry Docks.—Efforts have been made from time to time in testimony before Congressional Committees, in the public press and in pamphlet literature, to show that the cost of maintenance of dry docks of timber is much less than that of docks of stone. In 1897 the Simpson Dry Dock Company, of New York, issued such a pamphlet, which, since it is a public argument for timber and against masonry as the material of national and other dry docks, may be properly discussed herein. The pamphlet states that "the estimated cost of repairs to all of the docks is based upon close observations and our experience of over forty years." Estimates, it may be said, are not facts; and it would appear that the absence of exact knowledge as to the cost of maintenance of the various national docks has led, in this pamphlet, to deceptive conclusions. It should, as well, be repeated emphatically here that a just comparison of the maintenance of the two classes of docks can be based only on the cost of repairs to the dock structure proper, excluding all accessories, such as caissons and pumping plants.

Mr. Cathcart.

The Simpson pamphlet estimates the total cost of repairs to the Stone Dry Dock at the Navy Yard, New York, from its completion to 1897, as $250 000, an average of $5 434 per year. Excluding accessory structures, the actual figures, as already given, are $210 618, or $4 680 per year.

Again, there is given a total of $16 000 for general repairs to Timber Dry Dock No. 2, at the Navy Yard, New York, an average of $923 per year. The facts are that the repairs to the dock structure proper were only $1 982, or $270 per year; but, as already shown, the cost of repairs, renewals and reconstruction of the entrance will be $300 000, which will bring the yearly average for repairs to the dock-structure proper up to $30 198. It should be stated, however, that when this work is completed, no further repairs will, probably, be required for a considerable time.

The Simpson figure for general repairs to the Granite Dry Dock at Norfolk since the year 1865, is $125 000, or $3 906 per year. It will be observed that this is not claimed as an actual, but as an estimated, expenditure. In the Government report, of the Board on Dry Docks, of 1898, the total repairs from 1882 to 1897, only, are given. It is therefore to be presumed that there are no data available as to expenditures during prior years. This report gives a total outlay, for these 15 years, of $61 430, of which only $18 776 were applied to the structure proper, a yearly average of but $1 251. The Simpson estimate is from the year 1865, and it is a matter of history that this dock and its gate were seriously injured by the Confederates during the Civil War. Large amounts were spent in repairing the damage caused by their attempt to blow up the dock, and, even if the Simpson estimate be received as correct, it is apparent that the bulk of the expenditures must have been unusual and not due to ordinary wear and tear.

With regard to the Timber Dry Dock at the Navy Yard, Norfolk, the Simpson Company estimate the repairs to the dock structure, up to the year 1897, at $6 000, or an average of $818 per year. The expenditures given by the Government Dry Dock Board must, however, be regarded as authentic. These show, on analysis, that during this period the repairs to the structure proper of this dock amounted to $13 576, or an average yearly cost of $1 697, and when, in the current year, the repairs appropriated for and now being made are completed, the average annual expenditure will have been $4 857 upon the dry dock structure proper.

The Granite Dry Dock at the Boston Navy Yard is estimated, in the Simpson pamphlet, to have cost for general repairs, from its completion to 1897, $150 000, or a yearly average of $2 343. The Dry Dock Board gives the total expenditures from 1866 to 1897 as about $131 000, of which one-half was upon the dry dock structure proper, making an average yearly expenditure upon the latter of about $2 000.

Mr. Cathcart. No precise record seems to have been available giving the cost of repairs in detail prior to 1866; but the Board states that during the years 1855 and 1857 about $21 000 were expended upon new engines. It is more than probable that the repairs to the dry dock structure proper, from the time of its completion down to 1866, were very slight, since the annual report of the Chief of the Bureau of Yards and Docks for the year 1853 states that the stone dry dock at Norfolk had then been in use for twenty years, and was in perfect condition.

It would appear, therefore, that at least $21 000 of the general repairs, estimated in the Simpson pamphlet at $150 000, must have been applied to the pumping plant prior to 1866, and, if this estimated total of general repairs is correct, the average expenditures upon the dry dock structure proper, from its erection to the year 1897, must have been very much less than $2 000 per year, probably about half that amount, since the Dry Dock Board gives about $65 500 as the expenditures upon accessories from 1866 to 1897, and a further amount of $21 000 as spent upon new engines in 1855 to 1857. These two items make a total of $86 500, which leaves but $63 500 of the Simpson estimate for the maintenance of the structure proper during about 65 years, an average of less than $1 000 per year.

In referring to the concrete and granite dry dock at Mare Island, Cal., the Simpson Company began their estimate of repairs from the year 1891. From this time to 1896, they give the general repairs as $25 000; to this they add $50 000 for a new caisson—which was a duplicate and not a replacement—obtaining thus, for general repairs, a most erroneous total of $75 000, with an absurd yearly average of $12 500. As a secondary proposition, they state, that, if the item of the caisson be omitted, the repairs will average $4 166 per year, and add, finally, "this is claimed to be a modern, stone dry dock in every respect."

These estimates will now be studied in the light of the facts. A statement, as to the actual expenditures upon this structure and its accessories, obtained upon inquiry, gives the total for repairs, from the dock's completion in 1891 to 1897 inclusive, as only $14 406.86, of which amount $8 258.55 were upon the pumping plant, $4 534.59 upon the caisson, etc., and but $1 613.72 upon the dock proper, an average of $230.53 per year during this period of 7 years. The average expenditure for general repairs was $2 058.12, which figure is just half of the corresponding Simpson estimate.

The cost of the caisson mentioned has no bearing either on facts or estimates as to repairs. It is a duplicate, built as a relief for that within the dock, and its cost, $50 000, belongs to equipment, not to repairs. There is no place at or near Mare Island where an injured caisson could be docked; and, in view of this isolated situation, the Navy Department decided to have the duplicate built.

The erroneous estimate of $25 000 for general repairs, as given above, can be accounted for only by the supposition that there were included therein certain expenditures made in 1896 for a 40-ton crane and track for use about the dock, which, as with the duplicate caisson, must be classed as equipment, not repairs. Mr. Cathcart.

It will be seen, therefore, that the repairs to this "modern stone dock" were practically insignificant, in respect of the structure proper and exclusive of the accessories, which are of a class belonging to all dry docks.

The Simpson statement as to the timber dock at the Navy Yard, League Island, gives an amount of $10 000 for repairs and improvements from March 4th, 1891, to January, 1897, a period of about 6 years. By deducting $4 000 for raising the coping and $5 000 for repairs caused by the method of carrying out the work upon an adjacent wharf, the cost of maintenance of the dock is reduced to a total of $1 000, and an average of $166.67 per year.

As has been shown previously, Congress has appropriated $64 000 for repairs to be made during the present year to the structure proper of this dock. It is scarcely necessary, therefore, to challenge the estimate as above, since this appropriation alone gives a yearly average of over $7 000 for repairs to the dock proper.

The timber dry dock at Port Royal, S. C., was not built by the Simpson Dry Dock Company. Their pamphlet gives an estimate for general repairs to dock and accessories of $5 000 for the 2 years, or $2 500 per year. This yearly average is believed to be substantially correct.

In concluding the analysis of the cost of maintenance of the various national dry docks, as estimated in the pamphlet issued by the Simpson Dry Dock Company, it is desirable to state that this analysis has been undertaken only in view of the fact that this company is foremost among the advocates of timber dry docks, and that its arguments, as published in this pamphlet, and as presented to the Naval Committees of the two Houses, have had much influence in shaping the action of Congress with regard to the material of construction for the national dry docks.

In considering the cost of repairs to timber dry docks, as given in this pamphlet and in other arguments presented by the advocates of modern docks, it will be noted that the timber docks of the Navy, which are cited as examples of the small expense of maintenance for this material, range in age from but 2 to 10 years. Being thus practically new, it is obvious that their deterioration cannot have progressed sufficiently to give a true indication of the cost of repairs in the long run. For a correct estimate as to the latter, the comparison must extend over a period, at the close of which decay shall have reached such a stage that it will be necessary to make repairs sufficiently extensive to

Mr. Cathcart. restore the dock to its original sound condition. In other words, make the comparison, not on repairs for temporary patch-work, but on the reconstruction of a fair portion of such a dock, built, as it is, of perishable material.

Even such comparison as it has been possible to give herein, from the data of these practically new timber docks of the Navy, will show, however, that their yearly cost of maintenance, as presented by the advocates of wooden structures, is misleading and far below a correct measure of this item. These docks are certainly equal, if not superior, to the average of timber dry docks constructed elsewhere. It is not possible to admit that their care is in incompetent hands; and yet, it is clearly apparent that their cost of maintenance is very large, exceeding greatly that given in the pamphlet referred to and in other reports.

The comparison instituted herein has been based upon the cost of repairs to the dry dock structure proper. The advocates of timber construction seem to prefer a comparison founded on the entire general repairs of the docks, including all accessories, such as caisson, pumping plant, etc. It is submitted, that, even if the latter method were proper, the showing which has been presented to the public is unfair, in that the timber docks, being from but 2 to 10 years old, have not reached a time when these accessory structures require renewals or extensive repairs. To obtain correctly this yearly average for general repairs, which timber advocates prefer, this stage of renewals to accessories must be awaited. When it shall have been reached, it is plain that the comparison will be much more unfavorable to the wooden dock.

With regard to the stone docks of the Navy, it must be said, also, that the cost of their maintenance, as presented by their opponents, is largely misleading. The comparisons given, as to these docks, by timber advocates, are founded, not upon the maintenance of the structure proper, but upon the general repairs to the dock and its entire accessories—a principle which is obviously wrong. The errors arising from the adoption of this method are magnified in this case by the very considerable age of the majority of these four docks, two of them being 65, and one 48 years old. The repairs to the accessories form, therefore, a very large proportion of the total cost of maintenance, amounting, with the dock at Norfolk, for 15 years, to 70% of the total; with that at Boston, for 31 years, to 53%; and with that at Mare Island, for 7 years, to 89 per cent. The maintenance of the timber docks, on the other hand, if including repairs of all kinds, has not, because of their youth, comprised any considerable expenditures upon caissons, gates or pumping machinery.

In summation, it may be said that the data set forth herein would appear to show conclusively that the average yearly expenditure for the repair and maintenance of a masonry dock, built in the best manner

and of superior materials, is inconsiderable, both in the aggregate and in the percentage of the original cost; while the same items, with regard to the timber docks of the Navy, are unquestionably very large. Mr. Cathcart.

In view of the fact, that, for 10 years past, the Government has been practically committed to the policy of timber docks, having, within that period, built six of this material, and, of the further fact, that, by recent legislation, three more of these structures are authorized, the subject is presented to the members of this Society for discussion. The growth of the United States as a nation, and the results of the recent war, foreshadow an early and considerable increase in the force afloat. The defense of a coast line, extraordinary in extent; the acquirement of territory beyond the sea, which must be held—as it was won—largely by the Navy; the probable entry of the United States into Asiatic politics; and the prospective revival of the merchant marine, which the fleet must lead and guard—all point to this. The full consideration of any factor, therefore, which is essential to naval strength—as a trustworthy system of dry docks surely is—must be of interest, not only to the engineer, but to every man who has at heart the welfare of the country's gallant fleet.

TABLE No. 1.

Dock.	Years.	Total on dock proper.	Average, dock proper per year.	Previous average per year.
Stone, Boston	31	$62 000	.....	$2 000
Stone, Norfolk	15	18 776	.....	1 251
Stone, Mare Island	7	1 613	.....	230
Totals	53	$82 389	.....	$3 481
Average	17¾	27 463	$1 558*	1 160
Timber, No. 2, New York	10	$301 982	.....	$30 198
Timber, League Island	9	74 202	.....	8 245
Timber, Norfolk	10	48 576	.....	4 857
Timber, Port Royal	4	16 262	.....	4 065
Totals	33	$441 022	.....	$47 365
Averages	8¼	110 255	$13 364*	11 841

* The item $1 558 is on the basis of three docks at 17¾ years per dock. Similarly, the item $13 364 is based on four docks at 8¼ years per dock; $13 364 is about 8½ times $1 558; or, taking previous averages, $11 841 is about 10 times $1 160.

Commodore GEORGE W. MELVILLE.*—This subject, in the speaker's opinion, is of prime importance to the further development and maintenance of that strength upon the sea, of which—more and more as the years pass—the nation will find itself in need. Com. Melville.

* Chief of Bureau of Steam Engineering, U. S. N.

Com. Melville. With the acquirement of distant island territory, swarming with bronze-hued aliens, "The White Man's Burden," of which Kipling writes, in the civilization and enlightenment of "the silent, sullen peoples," is laid at last on the broad shoulders of the United States. With this there looms up as well a golden future on the Pacific, in the extension of the nation's trade to its uttermost island and to the vast Asian littoral beyond. Finally, the time seems ripe for the merchant marine to take again its proud place as of old, when its flag streamed over every sea.

These considerations point with no uncertain hand to the nation's need in the early future of a strong force afloat; and, in maintaining the efficiency of that force, a worthy system of dock construction is a cardinal essential. The speaker desires, therefore, to place on record his opinion—as he has done in the past—with that of the Secretary of the Navy, with that of his distinguished colleague, Commodore Endicott, and with that of his predecessor, Admiral Matthews, as being opposed most strongly to the flimsy structures, costly in their weakness, which have been built as timber dry docks for the Navy. As to the use of wood for the docks of private corporations, the speaker has nothing to say. It is plentiful and cheap; the average draught of merchantmen is light; the structures are less costly; and the exigencies of private business may require them. With Government constructions, however, none of these considerations holds. A wise nation builds, not only for its generation, but for its sons of the coming years; and we, in our day, are not true to this principle in the timber-veneered excavations, perishable and perilous, which, for 10 years past, have been inflicted upon the Navy.

The speaker will consider, first, the comparisons which have been advanced by the opponents of stone docks, with regard to the first cost of the two types. In this matter it has been the practice of some timber advocates to compare the cost of wooden docks, built by contract for the Government, with that of granite docks constructed in the navy yards by day's labor, extending over a long series of years, as appropriations were made from time to time by Congress. Thus, it is found that the Simpson Dry Dock Company, in its public arguments, has instituted such comparisons as to first cost between its own timber docks, built by contract for the navy in from 22 months to 2½ years, with stone docks the construction of which by the Government extended, respectively, over 6, 10 and 19 years.

Such comparisons are grossly unfair. The only just system as to this would be to compare timber docks and stone docks built under exactly the same conditions; that is, by contract, after public advertisement, under authority from Congress to enter into contract for the full completion of the docks at the earliest possible date. For the first time in the Navy's history it is now possible to compare the relative

cost of timber and masonry docks of approximately the same size and to be built under substantially the same conditions. Com. Melville

The proposals opened recently for a dry dock at Boston will furnish a fair comparison in this respect. The lowest bids for this structure show that the Government will be able to build by contract a dock of the very largest size, constructed of concrete and stone masonry, within the sum of $1 000 000, or at an advance of but 25% upon the amount appropriated by Congress for each of the three timber docks now authorized. In view of the cheapness of wood, as compared with concrete and stone, it would appear either that its manufacture into a timber dock is a somewhat costly operation, or else that there is a very large profit included in the sum appropriated by Congress for these timber docks. The matters of first cost and of cost of maintenance, however, are minor issues only, which should have no determinate bearing.

The real question is the stability and safety of a structure which may, at any time, hold within it a great battleship, costing millions of dollars and swarming with hundreds of men. The nation, to save dollars, cannot afford to imperil its naval strength or to risk human life; and these very things its policy of unwisdom as to docks compels daily in the entrance of ships into structures which have shown, time and again, their weakness. None of the timber docks of the Navy exceeds 10 years in age, and yet abutments have moved inward, and other injuries, more or less serious, have occurred to them, extending from the bursting in of the altar system, as at League Island, Port Royal and New York, to the distortion of the floor of the dock, as at Port Royal, and the partial collapse, in the case of Dry Dock No. 3 at New York. That no catastrophe—great in financial loss and appalling in the destruction of life—has yet occurred, is due solely to the care and skill of those in charge of these weak docks. The battleship *Massachusetts* was saved—during the partial collapse of Timber Dock No. 3 at New York—only by the hasty flooding of the structure and the hurried removal of the ship from its treacherous grasp.

In discussing the relative strength of the two types of docks, the opponents of stone lay stress only upon the capacity to withstand the vertical thrust of the ship upon the flooring of the dock. The stone dock may rest on a bed of natural rock, or in one of impervious clay, or upon piling foundations. The timber dock is built always upon piles. The calculations referred to, therefore, in the most difficult cases, consist simply of those based upon the strength, penetration and cross-section of the piling, involving but little engineering skill. These statements are *ex parte* and fallacious, and ignore wholly the inherent and vital weakness of the timber dock, which lies in its tendency to inward collapse under the hydrostatic pressure horizontally

Com. Melville. and from without, upon its sides, and vertically from beneath, upon its floor.

No such danger threatens a properly constructed dry dock of masonry. With good materials and workmanship, it is possible to make it absolutely water-tight, and the structure has, in itself, a weight more than sufficient to withstand the hydrostatic pressure from without. Stone and concrete give it that weight, and, since these materials, when properly embodied, will last for centuries, that weight can never be lost. For all practical purposes, the stone dock is as enduring as the everlasting hills.

With the timber dock the case is radically different. Its integrity —fleeting, at best—depends solely upon success in pinning it to the ground. Such a dock has merely a thin veneering of timber, lining the excavation and held down by piles driven into the soil, to which piles the timbers are bolted. It would be, obviously, both futile and dangerous to attempt to exclude from such a structure the entrained water in the surrounding soil. The timber dock, therefore, is one of tight joints only in the abutments, being open as a sieve elsewhere, and leaking, more or less, as the amount of water in the circumjacent ground is large or small. It lacks utterly, therefore, the tightness and weight which give stability and permanence to the dock of stone.

Furthermore, it is apparent that this hydrostatic pressure—which, in graving docks, is the chief force to be met and guarded against—increases with the depth. As this dimension increases, therefore, the more unfavorable become the conditions for the wooden dock, which has relatively no inherent weight to oppose resistance to pressure from without. With such increase, its stability and safety suffer rapid decrease, and there is swift growth in the tendency to rupture the bottom and sides. From this point of view, the question becomes one of great importance and risk, with regard to the very deep docks which are now necessary for the larger cruisers and battleships of the Navy.

It has been shown that the leakage of the timber dock depends simply upon the amount of water present in the adjacent soil. Now, this very leakage, which in one sense is an element of safety to the structure, is, in another, a source, ultimately, of sure and grave danger; for soil is carried in with the leakage, the latter increases, and there is displaced finally so much material as to cause at least a partial failure. This was the case recently in Dry Dock No. 3, at the Navy Yard, New York.

In a stone dock, however, a leak is not followed by such results, since the structure is homogeneous and all joints are water tight. The failure of one or more of the latter does not, therefore, involve necessarily the failure of others. As a matter of fact, the stone docks at the Navy Yards of Boston and New York have leaks to-day which have

existed for many years without measurable increase and without involving the structures to any extent. It is true that the masonry at the entrance of the Boston dock has been displaced slightly by the action of frost upon the open joints; but the weight of the structure is such that, if these joints were all open, it would still act as a dry retaining wall or arch, without danger of failure. Com. Melville.

At least two of the timber dry docks of the Navy suffer from excessive leakage, with its resultant dangers. At the Norfolk yard, the wooden dock is founded in a bed of clay of excellent quality, and the leakage is very small. That of Timber Dock No. 2, at the Navy Yard, New York, amounts to little more than 100 galls. per minute, which is moderate, considering the character of the soil. The leakage of the timber dock at Puget Sound, is not much more; but this is due chiefly to the fact, that, in the construction, provision was made for admitting the water from the soil, through a system of sub-drains and valves, into the drainage culvert, and thence to the pump-well, from which it is discharged by the drainage pumps. This was done in order to relieve, largely, the bottom of the dock from hydrostatic pressure.

With the wooden dock at League Island, however, no such advantageous conditions prevail. It has always leaked excessively, the amount entering from the surrounding soil varying from 1 200 to 1 700 galls. per minute. This great volume taxes fully the drainage apparatus originally installed; and, to obviate the inconvenience and risk which would arise from the failure of this pump, a duplicate apparatus has been erected. This duplicate pump stands to-day an eloquent, if silent, monitor as to the unwisdom of the wooden dock for national use. When a ship is in the dock and it is necessary to keep the floor dry, one of these drainage pumps runs constantly.

At the Port Royal Dry Dock, the leakage is about the same, and it was found necessary to fit reliefs very largely in the bottom and sides, in order to prevent a recurrence of the upheaval and rupture of the structure, which occurred about the time of its completion.

The foregoing has referred to the stability and safety of national docks of wood, in the past. The speaker will now examine briefly the programme for the future. In the Act of Congress, approved May 4th, 1898, there were authorized four new dry docks for the Navy, one each at Portsmouth, Boston, League Island and Mare Island—all to be of the largest size. All these docks were to be of timber, at a cost not exceeding $825 000 each; but the Secretary of the Navy was authorized, in his discretion, to build one of granite, or concrete faced with granite, the limit of cost, in this case, being increased by $200 000.

In the exercise of the discretionary powers lodged in him, the Secretary of the Navy decided to build the dock at Boston of granite, or concrete faced with granite. As stated previously, the bids for this

Com. Melville. dock fall considerably within the appropriation and are about 25% in excess of the amount appropriated for each of the wooden docks.

The absurdity of a further continuance of the policy of extravagance and disaster in the building of wooden docks is shown, not only by the facts above given as to the relative costs of the types, but by further facts with regard to the soil in which the proposed docks are to be located. For instance, that to be built at League Island will meet the same adverse conditions to which its timber predecessor there has succumbed. The soil there contains a stratum of compact sand and gravel, which is water-bearing, and the surface-water, when it meets this stratum, flows into the dock, the latter acting as a huge drain. Shall there be erected at League Island, more duplicate pumps, as costly monuments to the timber folly?

Again, borings at the possible sites for the proposed timber dock at Portsmouth, N. H., show, thus far, that the excavation for this dock must be blasted from granite, and then, to comply with law, be lined with wood. The advocates of timber could ask no deeper devotion to their theories and interests, than this.

In the speaker's view, Congress has acted in this matter without full knowledge of all that bears upon the case. Commodore Endicott, in a report to the Secretary of the Navy, which has been transmitted to Congress, has set forth the facts with clearness and great strength. The matter is of such importance to the future of our gallant fleet, that its discussion cannot be too wide. As an engineer who has served both on land and sea, the speaker regards it, therefore, as a duty and a pleasure to present his views on this subject.

Com. Endicott. M. T. Endicott,* M. Am. Soc. C. E.—It is probable that the first dry docks were constructed in Great Britain. It is known that, in the time of Queen Elizabeth, docks for the reception of vessels needing repairs were made by excavations into the soil bordering water-ways, lined with timber and backed with clay to protect the floor and sides, and fitted with gates at the entrance to shut out the water. The vessels at that time were quite small and the docks were of corresponding dimensions.

In the time of Charles II several docks were constructed in English ports, for the use of the British Navy, which were of considerable size. These were also of timber.

So far as the records now show, all the earliest docks were of wood, and were what are now called graving docks; that is, the dock was formed by making an excavation in the earth and lining the bottom and sides, thus forming a receptacle for the vessel, into which it could be floated, landed upon supports, and left accessible for examination and repairs when the water should be exhausted from the dock. As time went on, and larger and better docks were called for, the con-

* Chief of Bureau of Yards and Docks, U. S. N.

struction gradually changed, and brick and stone came into service for the construction of certain portions of the docks, and at present there are on the Thames many docks which are built of all these materials in combination; that is, partly of wood and partly of brick or stone, and, in the case of those of later construction, of concrete, also. Com. Endicott.

The transformation has progressed in Europe to such an extent that, at the present time, practically all the large docks are built exclusively of masonry, classifying concrete, for the present purpose, under the head of masonry, although strictly speaking it is not. The records, so far as accessible, show that abroad there are no constructions of this kind in timber. The present Chief Constructor of the Navy, Mr. Hichborn, who visited Europe in 1885, states that at that time the later docks were built largely of concrete, and were of the most substantial construction; and speaking of those on the Thames (private docks), a number were built of wood, but the principal docks were of masonry or concrete.

Masonry docks are the outgrowth of some centuries of experience in the construction and use of works of this kind. In foreign practice, it is a case of the survival of the fittest.

The first dry docks in America were constructed by the United States Government, and were begun about the year 1828. Before these were undertaken, Congress authorized the Secretary of the Navy to engage a skilful engineer to prepare the designs for these structures, and Colonel Loammi Baldwin, of Boston, Mass., was employed. He came to the duty well fitted for the work, having prepared himself especially by a visit to Europe for the purpose of studying structures of this class. With the experience of the Old World before him, he very wisely decided to model the structures for this Government after those which had been evolved from the experience of so many years abroad, and he made the two docks then authorized for the Navy, at Boston and Norfolk, the finest examples of fine masonry in submarine works that then existed in this country. They were regarded as among the best and most creditable public works built for the Government up to that time, and were pointed to with pride as works showing great skill in design and execution, and well adapted for the purpose of docking and repairing the vessels of the Navy.

The construction of these docks extended over several years, and they were not completed until 1834. They were built at a comparatively moderate cost, the Boston dock costing about $677 000,* and the Norfolk dock about $943 000. Both were substantially founded upon piles, were built entirely of stone, and were faced with cut granite of the finest quality and workmanship.

The granite dry dock at the Brooklyn Navy Yard, completed in 1854, followed, and, for various reasons, was a very expensive structure,

* This dock was afterward extended in length, bringing its cost, to date, up to $972 000.

Com. Endicott. costing $2 000 000; and then came the dry dock at Mare Island, Cal., which is a concrete structure lined with cut granite.

In the interval between the construction of the Boston and Norfolk docks, and that at Mare Island, the Government built several floating dry docks of wood. Two or three were of the balance type, that is, of one section, and several others were of the sectional type, and in the case of those 300 ft. or more in length, the sections numbered as many as nine. The balance docks were used in connection with shallow basins, as were the sectional docks, in order that a ship, taken up by the floating dock, could, by the sinking of the dock upon the floor of the basin, be hauled out upon a railway on shore for extensive repairs, while the dock could be used for docking vessels for slight repairs, not requiring hauling out.

It is not the purpose to discuss the merits of floating docks. This is simply mentioned as an incident in the history of the dry docks of the Navy. They had their day, but not proving so satisfactory, durable or convenient as the masonry graving dock, they were not replaced. They gradually deteriorated so much as to require extensive rebuilding. To-day only one of these docks remains in service, that at the Portsmouth, N. H., Navy Yard, and it is now safe only for vessels weighing a little more than 1 000 tons.

The timber graving docks of the present day in the United States did not originate in the Navy. They were constructed first on the Great Lakes. A timber dock built at Buffalo, N. Y., as early as 1840, was inspected by the speaker a few years ago, when he was assured by the officers of the company then owning it, that it was built not later than the year named. The speaker has been led to believe, from some investigations made since, that it was built even earlier than that time, and that the timber graving dock made its appearance in this country as early as 1837 or 1838. Others followed, and many docks of this type are now to be found in Buffalo, Cleveland, Chicago, Detroit, Port Huron and other places. While they differ in details from each other and from those built on the Atlantic coast, they are all of the same general type, in that the excavation is lined entirely with wood secured to piles driven in the bottom and upon the slopes of the sides, and faced with longitudinal timbers, forming steps or altars upon the sides.

The first timber dry dock built upon the Atlantic Coast was at Boston, Mass., in 1854, fully 14 years after the construction of a similar dock upon the lakes. It was of the same general construction, and differed only in details. Other docks upon the Atlantic Coast followed, all built by J. E. Simpson & Company, so that here this type of dock has come to be called the "Simpson" dry dock.

About the year 1886 the question of the construction of additional dry docks for the Navy became an important one, as the Navy was

building vessels of steel which required frequent docking; and, as the old sectional docks were disappearing, the need for further docking facilities was felt. Com. Endicott.

Without entering into all the reasons which led the Government to abandon the construction of masonry docks and take up with those of timber, it may be said that this was due to the advocacy of this type of dock by persons in civil life who were interested in their construction, and by a few officers inside the naval service who had championed the cause of this type.

The timber dock was presented to the attention of the Navy as possessing not only many good qualities, but many far superior to those of the stone dock. The most attractive arguments presented by the advocates of the former were its cheapness, its convenience in the way of accessibility to the floor by the gently sloping sides and low altars, its width on top, admitting light and air freely, its immunity from the disintegrating effects of frost, and its greater comfort for workmen in winter weather. A negative advantage, as urged recently by one of its strongest advocates, before the Senate Naval Committee, is that "it will last 40 years, and that is long enough for anything to last."

The arguments advanced by its advocates were successful in securing favorable action in the committees of Congress, and the first appropriations for timber dry docks were made in 1887, providing for two, one at the New York yard and one at the Norfolk yard. These were followed by one at the League Island yard, completed in 1891; one at the Port Royal Naval Station, completed in 1895; one at the Puget Sound Naval Station, with a masonry entrance, which was completed in 1896, and one in the New York Navy Yard, called Dry Dock No. 3, completed in 1897. The Government was thus fairly launched on the policy of the construction of timber dry docks, and it seemed as though it would be impossible to again secure an appropriation from Congress of an amount sufficient to build a masonry dry dock; in fact, the acts making appropriation, in almost every instance, as well as limiting to an amount only sufficient for a timber dry dock, provided specifically for one of such material.

The last Congress made provision for four timber dry docks, to be constructed, one each at Portsmouth, N. H., Boston, Mass., League Island, Pa., and Mare Island, Cal., but provided that the Secretary of the Navy might, in his discretion, build one of them of granite, or concrete lined with granite, and in such case the limit of cost was to be increased $200 000, to a total of $1 025 000. The Secretary exercised the authority granted by this act by deciding that the Boston dock should be of granite or concrete lined with granite, and plans and specifications were prepared for a dock of this character. Bids were opened on January 31st, 1899, in the Bureau of Yards and Docks, and resulted in a proposition providing for a dock with granite facing and

Com. Endicott. concrete backing, complete, for about the amount of the appropriation, or about $1 000 000. This result was much more favorable than anticipated, and showed for the first time that a masonry dock of the largest size and the best construction could be built for a sum not greatly in excess of the cost of a timber dock of the same general features and dimensions.

Prior to the final passage of the act making appropriation for these last-named docks, the Department had been before the Senate Naval Committee in advocacy of the construction of granite rather than timber docks, and the Board on Dry Docks, appointed by the Department in 1897, had reported recommendations which were, in effect, in favor of the policy of docks of masonry instead of timber. This report was laid before Congress by the Department. The Department had thus taken such steps as it might to bring to the attention of Congress its views and advice in the matter of the construction of these important structures, and the action of Congress, having been substantially adverse to this advice, the Department was not disposed to pursue the matter further with respect to the docks then authorized and provided for.

The possibilities in the way of the construction of masonry docks, as shown by the letting just referred to, were of such importance that the Bureau believed it advisable to bring them particularly to the attention of the Department, and, through it, to Congress, with a view to securing a reversal of the action already taken in the act referred to.

The subject of the advisability of constructing these works of stone rather than of timber had received much attention from engineers and from the press, and there seemed to be a wide interest in the matter, and a strong public sentiment against the course prescribed by Congress with reference to the material of which they were to be constructed. It had also become quite apparent that the general sentiment among officers of the naval service who took an interest in the matter and had paid much attention to it, was, with very few exceptions, strongly in favor of masonry docks. Altogether, it seemed to the Bureau that the result of the bids for the Boston dock indicated that the time had arrived for the Department to make another effort to save the Navy from the construction of more timber docks. In making such a move there seemed to be a prospect of success, and the Bureau addressed a letter (published in the New York *Tribune*), to the Secretary of the Navy, strongly urging the Department to make another effort with Congress to abandon the construction of timber dry docks and re-enter upon the policy, which it instituted in the early years of the century, of building for its Navy the safest and best dry docks, and which had become the policy of all other first-class naval powers.

In pursuance of this recommendation, the Department has again

brought the matter to the attention of Congress, through its naval committees, and has laid before them the Bureau's recommendations in the matter, with its earnest approval. The matter has been brought up at an opportune time, for several reasons: Because the timber docks heretofore built are beginning to show that they are temporary and unsafe structures; because the proposals for the Boston dock show that a first-class masonry dock can be constructed for a reasonable sum and at a moderate increase over the cost of a timber dock; and because the public mind is alive to the subject and strongly in favor of good, substantial, creditable structures of this kind for the Navy. Therefore, the recommendations and efforts of the Navy Department, backed by a disinterested, logical and earnest sentiment, are almost sure to bring about a change in the present policy. Com. Endicott.

A timber dock is a temporary structure, and as the chief material entering into its construction is wood, it requires very extensive renewals at an early day, varying, according to the kind of wood used and the local influences, from 20 to 25 years, when they amount to a practical rebuilding of the upper portion of the structure, and frequently its entire reconstruction. While the first cost of a timber dock is small, compared with that of a masonry dock, the rapid deterioration referred to results in considerable expenditures at the end of a few years, if the structure is kept in good condition, and if the repairs and renewals are of an extent necessary to preserve the dock in a condition as safe and good as when completed. The experiences in the Navy, thus far, with timber docks, although extending over only a few years —the dock now longest in use having been built about 10 years ago— show that the expenditures necessary to restore them to their original condition at the end of this latter period are very considerable, and appear to be several times as great as those for a stone dock of about the same dimensions. For the purposes of a fair comparison the cost of the maintenance and renewal of accessory structures, as caissons, pumping machinery, etc., should be neglected, and a parallel should be drawn entirely between the expenditures made upon the dry dock structures proper; which, in the case of one, would be stone and concrete, and in the case of the other, timber.

The records of the stone docks of the Navy, as far as they have been collated, show that, generally speaking, the repairs are very small indeed; the only instance in which any individual repair has been of considerable magnitude being in the case of the stone dock at the Brooklyn Navy Yard, where the masonry joints became injured on account of the presence of springs and the action of frost. This condition was due largely to the fact that the cement used in the mortar for the joints was native hydraulic cement, not Portland cement. The work was repaired about the year 1886, the masonry at the entrance and some at the head being taken up and relaid with Portland cement

Com. Endicott. of the first quality. Although these repairs have been completed for many years, they appear to be entirely successful, and there has been no recurrence of injury to the joints. It seems quite safe to say that if high-grade Portland cement mortar had been used originally, there would have been no such trouble, and the work would probably have lasted until the present time without any material injury.

The records of the repairs to the stone docks extend over a great many years prior to the Civil War, and the collection of exact and full data in regard to the expenditures upon them is difficult, but those which have been examined and compiled are sufficiently extensive and accurate to be a fair index of the repairs to such structures.

Without repeating here the details and figures, it is to be said that the average annual cost of repairs upon the masonry docks has been very small indeed, and has amounted to a very trifling percentage of the cost of the work.

The records of the expenditures upon the timber docks and their present physical condition are full, exact and easily obtained, and show that not only is the cost of repairs per year very much greater than for stone docks, but that the percentage of the original cost put out in repairs is several times as great as in the case of the masonry docks.

In the matter of cost, the experience of the Navy has been that in the case of the masonry docks last built, it is large; but that those first built, comprising the docks at the Boston and Norfolk Navy Yards, although of the finest quality of cut granite, did not cost as much, being in each case less than $1 000 000. The large cost of the masonry docks was due to several causes; in the first place, they were not built by contract, but by day's work by navy-yard employees, and the materials were purchased or contracted for piece-meal. The appropriations for the work were made by Congress in such a way that labor and expenditures extended over long periods of time, thus enhancing the cost and resulting in decay and injury to the coffer-dams and accessory structures, and the disintegration of the soil exposed in excavations from the action of the elements, on account of the many seasons covered by the work.

The timber docks for the Navy were all built by contract, after public advertisement, and, by the authority of Congress, contracts were made for the entire completion, thus enabling the work to be taken in hand and pushed through with the greatest possible despatch. It will be seen, therefore, that the records of the Navy, in the matter of the costs of timber and stone docks as built, afford no fair basis of comparison, and one of the great advantages which has been urged in favor of the timber dock is the smaller relative cost. It has even been claimed that the interest on the cost of a masonry dock was sufficient to build and maintain a timber dock indefinitely. This comparison

has almost invariably been drawn between a timber dock built by contract, and either the New York or Mare Island stone docks, which latter were built by day's labor, the work extending through a long term of years. Com. Endicott.

An opportunity has been afforded recently for instituting a somewhat accurate comparison of the relative cost of these two types of dry dock by the proposals received for the construction of a concrete and stone dock designed for the Boston Navy Yard. These bids were based upon conditions very similar to those which obtained in the cases of the timber dry docks; that is, Congress having authorized the entire construction of the dock within a certain limit of cost, the plans and specifications were made and competitive bids were invited, after public advertisement, the work to be completed in a period not exceeding 2½ years, and as much shorter as the contractor may desire to make it.

These bids show that a dock of the largest size can be built of concrete lined with cut granite, and complete with all accessories, at a cost of about $1 000 000, or only about 25% in excess of the amount fixed by Congress as a limit of cost for each one of the timber dry docks to be built of the same size and under similar conditions. It will be seen, and must be admitted, that such a comparison is fairer and much more accurate than that previously referred to, where the cost of the timber dock by contract was about $600 000, and the cost of the stone docks at Mare Island and New York was $2 000 000 in one instance and $2 750 000 in the other.

This is the first time in the history of dry dock construction in the Navy that such a comparison of the cost, under similar conditions, has been possible. The result is, of course, beyond dispute, and so favorable to the masonry dock, in the matter of relative cost, as to be of the greatest value and significance. It shows that the relative costs of these works heretofore claimed by the advocates of the timber dock, and their general acceptance by the public, were wrong and misleading.

The claims set up for the timber dock, based upon these comparisons, have had great influence upon the public mind and upon Congress and its committees, and have resulted in the practical adoption of this type of dry dock for the United States Navy for the last twelve years, during which time the Government has more than doubled its docking facilities by the construction of six timber docks. While other claims have been made for the timber dock as superior to the stone dock, there is no doubt that the matter of first cost has largely determined the action of the committees in Congress; but the result foreshadowed in the proposals for the Boston dock is a permanent masonry dock at an increased cost of only about 25% over a temporary dock of timber, which would require extensive rebuilding in

Com. Endicott. 20 or 25 years, and also a small annual outlay for maintenance as against a very large one.

In the long run, the timber dock is much more expensive than the masonry dock. A masonry dock built by contract, after public competition, can be built in about the same time as a timber dock, at a moderate increase of cost and a small annual outlay thereafter for its maintenance, as against a timber dock 25 or 30% cheaper in first cost with a large annual expenditure for maintenance, amounting to a practical renewal every 40 years. The result shows that a masonry dock is cheaper than one of timber.

In weighing the relative merits of the stone and timber docks, in the matter of convenience for use, it can be stated that the conditions are practically the same. A timber dock, as usually constructed, is of great width at the top, which has resulted from an effort to construct the sides of the dock at the least expense and with the least danger of deformation, and the slope generally adopted is that natural to the soil, so as to avoid any considerable thrust from the earth tending to force in the sides. The side construction consists almost invariably of timbers superimposed in such a way as to form altars or steps from the bottom to the top. This makes the entire side construction practically a stairway; and the dock, being wide at the top, admits light and air freely.

Stone dry docks, as generally constructed, are not so wide at the top, and the altars or steps are of greater height. Stairways for ingress and egress are introduced at convenient distances. It has been put forth as a great advantage of a timber dock over one of masonry, that, owing to the form, the timber dock is much more convenient for access and admits more light and ventilation, thus facilitating the work in the dock. The materials of which a masonry dock is constructed lend themselves to any form, and one can be constructed of precisely the same outline as the ordinary timber dock. The general form or outline of the masonry dock is one which is almost universally followed in the construction, and, although less broad at the top than the timber dock, such construction results in no inconvenience or disadvantage to the work carried on in the dock, else the form would long ago have been changed to one more nearly approaching that of a timber dock. In the United States, the last masonry dock constructed, that at Mare Island, approximates very closely to the cross-section of a timber dock, and is a sufficient answer to the claim of the superiority of the timber dock in this respect.

It is to be observed, in this connection, that a dock very wide at the coping level is not without its disadvantages, in that it necessitates cranes, or appliances for handling materials, with very long arms to reach the center of the dock, and this has been held by European builders to be an objection to very wide docks. As a matter of fact, it

may be stated that the masonry dock of the ordinary form admits of all the light and ventilation necessary with a ship in dock. There is nothing to obstruct except the vessel itself, which will, in this form of dock, intercept considerable light, and render the portion of the dock directly under the vessel less light than other portions. It is not known that any difficulty has ever been experienced in any masonry dock through lack of sufficient light and ventilation. The only condition in which there would be any lack of light and ventilation would be in the case where the vessel contained in the dock was of such size, as to practically fill it. Where the cross-section of the vessel approximates that of the dock, this condition could only exist amidships, as the section decreases both ways from the center of the vessel. Com. Endicott.

In the matter of accessibility, while the timber dock affords a convenient stairway at any point, a stone dock admits of the installation of stairways at any intervals deemed necessary or desirable. It can be stated, therefore, with reference to the form of the docks, that the masonry dock meets substantially all the requirements of accessibility, light and ventilation, and, in any event, admits of the construction of precisely the same form or outline as a timber dock.

In the matter of the stability of the two classes of dock, the conditions to which they are subject are practically the same. The ability to sustain the weight of the vessel is met equally by the two, generally speaking. The condition involving the most danger to a dry dock, however, is not the weight of the vessel which it receives, but the pressure of the water contained in the soil below the level of high tide, which acts normally to the exterior of the dock, tending to lift the bottom and force in the sides. It needs little explanation to show that the dock which is capable of meeting this condition more successfully is the one of masonry. The timber dock is built of a comparatively light material, wood. Its weight is a very small element of stability, and its integrity depends upon the measure of success with which the access of water through the soil to the sides of the dock is prevented, and with which the wood, which constitutes the interior lining of the excavation, is pinned or secured to the soil underneath. This is effected by driving piles into the soil, to which the interior woodwork is secured by bolts. It will be seen that such a structure is not well designed for resisting the inward hydrostatic pressure, and in all timber dry docks it is the practice, particularly in those of considerable depth, to provide valves or inlets, through which the water in the soil may find access to the interior of the dock, and be carried away through the culverts to the pump-well, and thence be discharged into the harbor. It has been well said that the only way to preserve the stability of a timber dry dock is to let the water into the dock and then pump it out. The pressure of the water is particularly felt in the entrance works of the timber dock, which, being

Com. Endicott. near the harbor, are subjected to greater hydrostatic pressure, where the slopes are much steeper, and to the water pressure upon the sides is added a great deal of thrust from the soil. It has been frequently found in the timber dry docks that they have been incapable of successfully resisting this force, and in many instances the altars have been forced off, the sides of the entrance works have been forced inward to some extent, the bottom of the dock has been uplifted, and, where defects in the work have existed, an inflood of water, once set up, has resulted very disastrously, and endangered the entire structure. In a shallow timber dock this danger is much less, but in those of great depth, which are necessary for the accommodation of large battleships and cruisers, it is a very formidable one and is ever present.

Leaks in a timber dry dock, particularly a deep one, are looked upon with grave suspicion and require constant watchfulness, because, once started, they are particularly dangerous in a dock of this kind, as its structure, not being watertight, silt and soil may be carried in, undermining portions of the structure, and loosening its hold upon the soil to such an extent as to cause collapse or fear of collapse. This was the experience in the case of Dry Dock No. 3 at the New York Navy Yard.

In a masonry dock the structure is designed to resist by its own weight the forces referred to, and, as its construction is watertight, it embodies all the elements of stability and safety. Any leak which may occur in a structure of this kind, due to a faulty joint, is not attended with the same danger as in the case of a timber dock. The early stone docks, now 65 years old, have had for a great many years some leaks through faulty joints, but these have existed without any material extension of the trouble, and without involving any instability or danger; and these docks have preserved their integrity and usefulness without failure or interruption of any kind.

It is of the utmost importance that a dry dock be absolutely safe. Its collapse might prove to be exceedingly disastrous to property and to life. A valuable war vessel, costing millions of dollars and containing hundreds of lives, should be placed in no dock which is not absolutely safe in every respect, and about which there is no doubt. The feeling of security in placing a vessel in a dry dock under such circumstances is worth the expenditure of any amount of money necessary to provide the very highest type. Accidents of more or less serious character have occurred in the timber docks, but none has ever yet developed in a masonry dock, and the advantages of the latter, in the matter of stability and safety, are immeasurably greater than in the case of a timber dock.

A dry dock is a great public work and one of great utility, and should be, like other works constructed by the United States Govern-

ment, of the best and most substantial quality, and an example, in every respect, of the best practice in constructions of its class. In its material the Navy is not content with anything which is not the equal of the same all the world over. All other first-class powers of the world are building graving docks of masonry of the best, most substantial and enduring type. Is it left for this Government to content itself with cheap, temporary structures, unstable, or embodying the elements of danger? Com. Endicott.

R. G. PACKARD, M. Am. Soc. C. E.—The comparisons made thus far have been between the timber dry docks of the present day and the granite dry docks of many years ago. In such locations as League Island and Beaufort, S. C., especially, the present concrete structures, made of high-class cements, would be much more satisfactory than the timber docks, or even the old masonry docks that have stood so well, the record of which has been given by Messrs. Cathcart and Endicott. It would be interesting to know the number of days the docks have been in working order, and the cost of repairs per foot of length, and per foot of draught. In other words, how much per ton does it cost the Government for dockage? The comparison of cost made by Mr. Endicott is based on the highest class of concrete, and with more or less granite lining of high cost, and highly finished. Such linings may be a necessary feature, but, in making massive structures, such as these concrete basins, a less costly class of materials could be used, more or less saving might be effected, and an equally good structure secured. Thus the relative costs of timber and concrete structures might be brought nearer together than they are to-day. Mr. Packard.

P. C. ASSERSON,* M. Am. Soc. C. E.—The speaker's experience in repairing stone docks and in repairing and building wooden docks has been quite extensive. His first experience in repairing stone docks was at Norfolk, Va., where the entrance work had been destroyed by the explosion of gunpowder. The cost of repairing that dock was not very great. The greatest expense was incurred in rebuilding the caisson, which had been destroyed by fire when the yard was evacuated by the Confederates, because, although the inner abutment was destroyed, the outer sill was not damaged, and the repairing of the stone abutment required no great engineering science. It took three years, but the appropriations were small. The speaker's next experience was in rebuilding the abutments and outer works of the stone dock at New York, which had been disintegrated by the water finding entrance, principally from the sea. The chief cause of the trouble was bad construction, something rather surprising. It was found when the abutments were taken apart and the masonry taken down to the sill level, that in the abutments proper there was not a single header. The stones were all stringers, the same as one Mr. Asserson.

* Civil Engineer, U. S. N.

Mr. Asserson. brick laid on another, without a heading course. That was probably one of the principal causes of its destruction. The second cause was the poor cement that had been used. Only ordinary Rosendale cement had gone into its construction. A third cause was that someone had attempted to remedy the leaks on top by caulking the joints with lead, thus forcing apart the stone and admitting more water. The speaker believed this to have been a fatal mistake, and thinks the same thing has also occurred in other cases where lead caulking has been used instead of cement. In the repair of the Brooklyn dock it was found also that the sides had settled and split the head of the dock in three parts. At the head of the dock cracks were found which extended from top to bottom on each corner, and in some places the speaker could run his arm into the crack. Of course the water found ingress there, and frost following it helped to displace the masonry. In repairing, these things were all taken into account, and care was taken to put in headers where the masonry had been loosened. The cement used was the best, not that this country afforded, but that could be imported from Germany. The speaker believes that there have been absolutely no other repairs upon that dock since these were completed in 1888. It is in perfect condition, and will probably remain so for many years.

In the construction of the wooden dock, No. 2, at Brooklyn, the speaker had some experience—what some engineers would call "a great deal of experience." The basin of the Wallabout is underlaid by what some call quicksand. The speaker calls it mica sand, but does not know that there is much difference. It is very quick, however, and there are "only 90 ft. of it." In places it was found that piles 50 ft. long could be driven very readily and very quickly, but if the hammer was taken off quickly, the pile would follow it up again. To stop the quicksand the contractor resorted to close piling, ballast stone, bags of concrete and all sorts of expedients. Finally, after a great deal of trouble, the concrete was put down, and, by the friction of the sand on the piles, sufficient stability was found in the bottom to hold any ship that the dock would take; but with the sides it was different. The speaker does not think it is generally known, but shortly after the dock was built it was found that in driving home the wedges at the ends of the shores when docking a ship, the dock would go back or spread on both sides as much as 4 or 5 ins. That happens even now whenever a vessel is shored. It is only a question as to how long the diagonal timbers will bear the continual thrust on them. The soil that should pack up to the back of the timbers, and make them steady, is of such a nature that it falls away from the back of the altars and diagonal timbers, leaving the sides of the dock without any support on the back except the piles. The speaker regards the dock as unsafe for docking a heavy ship that has any list.

As long as a ship is perfectly upright and balanced upon the keel blocks, all will be well. Mr. Asserson.

The speaker saw the construction of the timber dock at Newfoundland. The bottom consisted of shale rock, and as piles could not be driven successfully, a concrete bed, 6 ft. thick, was laid down, and formed a very good bottom.

About two years ago the speaker repaired the outer abutments, the sill and the sheathing on the abutments of the timber dry dock at Norfolk, Va., which had been destroyed by the teredo. The cause of this destruction was as follows: When the *Texas* was being built at Norfolk, she was put in the dock to receive her armor, and kept there some nine or ten months. Unfortunately the caisson had been put on the inner sill, thus leaving the outer sill and abutment exposed. During this nine or ten months the teredo completely riddled and demolished the outer side sills as well as the surface planking or timbering of the abutment proper. The sills were completely destroyed from high-water mark to within 1 ft. of the bottom. There, the sill had been covered by mud, and was, of course, in good condition. The covering of the wing walls, extending out on the side, and the end sill of the wing walls were entirely destroyed. These wing walls had been covered by creosoted planking underlaid with ship felting as a protection against the teredo, and that fortunate circumstance had saved the inner plank, but the outer plank was completely gone, and in places had commenced to fall off. In a year or two more the inner planking of the abutment and of the wing walls themselves would have been completely destroyed. By degrees the wing walls and the abutments were stripped, and, by local cofferdams, the whole of the front covering was renewed at a cost of about $10 000. A new sill on each side of the dock was put in and overlaid with a built-up Z-bar of steel, secured in such a way that the sill will probably not be disturbed by the teredo for many years.

The speaker does not know of any chemical preparation with which wood can be treated whereby it will be enabled to completely resist the teredo for more than 10 or 15 years.

The speaker is familiar with the structure of all the docks from New York southward. The timber used in the facing, and subject to decay, has been merchantable timber of good quality, and has been nearly all heart wood, where it was possible to obtain it. Of course, in structures of that kind, where large quantities of timber are used, there will be a little sap wood, and there is no doubt that such wood begins to decay at once. That was the case with the dock in Norfolk, where, two years ago, the speaker commenced to repair the upper works. The piling, the cross-cap timbers and the diagonal bracings were found badly decayed from the coping to the low-water line.

The spreading of the sides of the dock previously mentioned is due

Mr. Asserson. to the difficulty of backing the soil up against the back of the altars when building. Further, being a disturbed soil, on a slope of 35°, it settles away from the altars, and, of course, the space left fills with water. The same trouble does not occur with the stone dock, where the retaining wall is vertical on the back.

The wooden docks have had the same care as the stone docks. Those who have been interested in dock construction for the last 30 years have had great anxiety in respect to all the docks, and they have been taking care of them as fully as possible. It would be necessary to be more careful in docking a ship in a wooden dock than in a stone dock, and a ship can be handled in a much more rough and ready manner in the latter than in the former, without danger of injuring the dock.

In handling material in a wooden dock care must be taken not to destroy the altars, a necessity which does not obtain, to as great an extent, in a stone dock. Less care is required in wedging against a stone dock than against a wooden one, though the speaker does not believe that any wooden docks have been injured by docking a ship, so far as he knows, nor have any ships been injured on account of docking in a wooden dock. But as the docks decay, of course injury may happen.

The speaker thinks that from the nature of the two materials, stone and wood, equally good construction cannot be obtained, and it is hardly possible to make comparison as to strength or durability. Sufficient timber could not be put into a wooden dock to afford a proper comparison with a structure of stone and concrete. In the speaker's experience, the construction of some wooden docks has been rather on the slimsy order of mechanism and construction, though he thinks the Anglo-American Company worked honestly and did the best they could with their wooden docks. Undoubtedly, the builders of wooden docks did the best they knew how, and exercised care, except perhaps in the case of a certain timber dock recently constructed.

The speaker can furnish no data as to the relative cost of good concrete or good wooden docks. It is only when a contract is made with responsible people that the relative cost of the two classes of docks can be ascertained. Wooden docks can be built for $1 000 per lineal foot, and stone and concrete docks can be built for $1 500 per lineal foot.

In the early days the speaker was in favor of wooden docks. Now, he is in favor of stone, or, rather, concrete and stone. He believes that in the future dry docks should be constructed of concrete, the best that can be made, faced or lined with stone, particularly in the wearing parts of the dock. There are parts of the dock, the wings and the angles, for example, that need not necessarily be of stone, as concrete will answer the same purpose.

In the Norfolk dock the upper part was recently rebuilt entirely of concrete, which made a very good job. The only reason for putting a wooden lining on the front of the concrete altars was to prevent the abrasion of the green concrete. The upper part of the Norfolk dock was repaired while the dock was in daily use, and the speaker thought it was necessary to do something to protect the concrete during construction. If he had had the money, he would have put in stone instead of wood, but the latter was put in in such a manner that when the planks split or became decayed they could be taken off and replaced by others. Mr. Asserson.

The speaker can see no reason why dry docks constructed wholly of concrete, and without stone lining, should not be satisfactory, if the corners of the altars are rounded off. He would prefer, however, to make assurance doubly sure, and use stone on the wearing parts, for the reason that there might be carelessness in shoring up ships. There is a probability that the corners of the concrete altars might be broken off, particularly where they are so shallow —only 8 ins. high—as in these structures. With a larger body of concrete, say 12 or 18 ins. high, the speaker would not hesitate to allow the use of altars wholly of concrete, because the corners of the altars themselves need not be touched. The corners of the concrete are sometimes broken off by sliding timbers and heavy material over them and down into the dock.

In reference to the lining of the timber docks with creosoted plank, it is a fact that the teredo will not attack it for several years. The teredo will not pass across a water-bearing seam. But creosote will protect only for a time. The speaker's experience has been that where creosoting has been throughly well done, a good, heavy, dead-oil creosote injected into the timber at a pressure of 100 or 120 lbs. per square inch, it will protect timber for from 10 to 15 years; after that the creosote is not so effectual. Unfortunately, the creosote used in the altars at the Norfolk dock was not the best kind. The speaker thinks it was what is called "pine oil," and he believes it helped to rot the timber more than to preserve it. However, the top of the dock at Norfolk is badly decayed for a distance of 8 to 9 ft. down from the coping.

The timber dry docks with which the speaker has had experience have all been constructed in about the same manner. There is a difference in the shape, but they have been practically earth excavations, having the sides lined with timber, the slope of the ground being such that it would stand by itself, except that at the Brooklyn yard the ground does not stand anywhere, but moves and sinks as soon as the mica sand has been reached.

Most of the Government's timber docks are good, but the speaker thinks there is room for improvement as to their strength, especially as regards the sides; the bottoms of the docks will no doubt last many years.

Mr. Asserson. There is no question in the speaker's mind but that in these days the Government should build for the future. Wooden docks were adopted by the naval service, not because of their durability, but because they could be built quickly and cheaply. Our need of docks was such that we could not wait for stone docks to be constructed. For 20 years Congress was utterly unwilling to appropriate large sums for dry docks, for repairs in the navy yards, or for building up the shops that were decaying.

Now that Congress and the country are willing to appropriate money, it is time to abandon that policy. Instead of building wooden docks, that serve at most only for 20 or 25 years, structures that will serve generations to come should be built.

The estimated cost of a concrete dock, 750 ft. long and lined with masonry, for Norfolk, Va., was $1 100 000. For a timber dock of the same size, and built as strong as possible, the estimate was $700 000. The estimate was for a concrete dock lined with stone 3 ft. thick, with stone abutments, and for a steel caisson, including pumping machinery. The stone lining was to have been set in the main dock chamber, far enough into the concrete to be firm and to form a tread or step, and with a very open slope—30 to 33°—so as to admit light and air, the same as for a wooden dock. There is no doubt that the shape of wooden docks is very good, because light and air are so readily admitted, and because access is so easy.

If first-class timber, or heart timber only, was put into a dock, and in a first-class manner, the dock would last 5 to 8 years longer than ordinarily, but all heart timber can hardly be obtained in such large quantities.

The wooden docks have served well to the present time, and the speaker thinks it is best to praise the bridge that carries us safely over. Nevertheless, he is of the opinion that we should now adopt material of a more durable character for structures that we expect to last and use for hundreds of years.

Mr. Tait. JOHN G. TAIT, Assoc. M. Am. Soc. C. E.—No one makes any attempt to deny the fact that a masonry dry dock is much more desirable as a government structure than a timber dry dock. Therefore the item of first cost must be the argument that influences the Congressional Committee on naval affairs when they decide to build timber instead of stone docks. As engineers, citizens and taxpayers, we are all interested in having the Government make the best investment, and build masonry docks, and to that end, until the Naval Committee are educated up to the advantages of stone docks, and while the engineers are still in competition with men advocating timber docks, any unnecessary cost should be omitted from the masonry docks.

At the site of the Boston dock the cost of concrete per cubic foot is less than half that of timber. This dock contains a great deal of gran-

ite, the stones are very deep, and, according to the plans and specifi- Mr. Tait.
cations the radial lines have to be preserved for the full depth of the joint, which makes very expensive cutting. Then, in addition to that, the same courses are continued from the main part of the dock out into the jaws, so that each stone constantly increases in width as well as being a voussoir.

These requirements probably make the cost of the dock about $200 000 more than it would have been if built entirely of concrete, or of concrete with granite quoins. If the dock had been designed with a smaller lining, and if there had been a different arrangement of the stones in the jaws, the bid would have been very close to that of a timber dock.

JOHN KENNEDY, M. Am. Soc. C. E.—Having recently examined all Mr. Kennedy.
the large dry docks on the Atlantic coast from Halifax to Norfolk, and on the St. Lawrence and Great Lakes, from Levis to Lorain, mainly with reference to the choice of material for the construction of a dry dock of large size at Montreal, the speaker will state some of the results of his observations.

The wooden dry docks of both public and private ownership show general weakness of construction, and a rather rapid decay. The decay is, of course, most rapid in the parts above water level, and it appears to reach farther down and be more rapid in docks in fresh water than in salt. For example, beginning at the North, the wooden dry dock at Portland, Me., built in 1869, has had no recent repairs, and its altars and pile heads above low water are entirely rotten.

At Boston the altars and other lining of the three wooden docks built in 1854 to 1864 have been practically all rebuilt inside, and have required frequent repairs. The largest one is leaking beneath the entrance. The two private docks at Erie Basin, Brooklyn, built in 1866, were all relined in 1881, and concrete substituted for wood in the upper five altars. The wooden dock at Cramp's, Philadelphia, built in 1876, has largely failed. The altars and the slopes near the abutments are bulged in badly at places; the altars, from weakness and decay, have been stove in at places, revealing cavities behind, from which the earth slopes have been washed down. The League Island dock of the United States Navy, built in 1891, is notably weak, and has bulged in badly. While occupied by the United States cruiser *Columbia*, a month ago, the abutments were shored up to prevent collapse. There are serious leaks of water and mud in the bottom and lower altars of one side, and the earth slopes behind the altars have run down in several places, leaving large cavities. Repairs, estimated to cost about $64 000, are about to be undertaken. The Norfolk Navy Yard dock, built in 1889, is now having the upper eleven altars renewed in concrete because of the decay, not only of the altars, but of the braces and pile heads which carry them. The

Mr. Kennedy. wooden dry docks visited on the Lakes are in much the same general condition.

The speaker found that all engineers of the United States Navy Department who have had experience in the working and maintenance of wooden dry docks, and with whom the question was discussed, were understood to be quite against wooden dry docks, at least for naval use, because of their weakness and short life. On the other hand, private owners of wooden docks are in favor of wood for their own service, and in adding a new dock they build either wholly or mainly of wood. The obvious difference of conditions will account for much of the difference of opinion. In Government docks a small saving in first cost is of minor importance, but weakness and frequent need of repairs are well nigh intolerable. On the other hand, in docks of private ownership, saving in first cost is usually of serious importance, while the cost of maintenance repairs is met by the earnings of the dock, and is less felt. It is to be noted, however, in the more recent private docks built by owners of experience, that there is a desire for something more permanent than wood. A notable instance is that of the large dock now being built by the Newport News Shipbuilding & Dry Dock Company, in which the abutments and wings are to be of concrete. In the Erie Basin docks, Brooklyn, the wooden altars above the water line have been replaced by concrete. It may be noted, too, that all the recent wooden docks, of which the speaker has knowledge, and the more ancient ones, also, have not been built under any patents, nor by contractors holding patents; or, in other words, while the building of wooden and partly wooden docks is still continued by private firms, the patented kind seems to have passed out of favor.

In Canada there are no wooden dry docks of importance. All the Government docks, three in number, are of stone and concrete. One of these, on the St. Lawrence, at Levis, Que., was finished in 1886; one on Lake Ontario, at Kingston, Ont., was opened in 1892, and the third, on the Pacific Coast, at Esquimalt, B. C., was finished in 1887. All are of excellent limestone ashlar, with concrete backing and inverts, and none have had any repairs of more importance than pointing, except in the caissons and other accessories.

Much reduction in the cost of stone dry docks has been made, by the substitution of concrete for part of the masonry, and it is proper to consider how much farther such substitution may be wisely carried, in cases where economy is of prime importance. The masonry of a stone and concrete dock is, of course, that in the linings, altars, copings, inverts, entrance and other parts where it is requisite that it be of cut ashlar, of expensive kind; and the further elimination of the whole or any considerable part of such costly work, rapidly reduces the average of the whole. There can be no doubt as to the strength

of solid concrete dock walls being fully as great as that of walls of concrete and ashlar combined, in which the bulk of the wall is of concrete and the ashlar is a mere facing. The real question is as to the wearing and weathering qualities of the inner surface and of the altars, if of concrete only. Examples of concrete of ample durability as well as of strength, can be pointed out, which show that good concrete will fulfill all needed requirements, even in northern climates. The making of Portland cement has also been so wonderfully improved, and the testing of it has become so simple and reliable, that there is now no doubt as to the obtaining of cement of an excellence and uniformity which was unattainable a few years ago. Mr. Kennedy.

In England and throughout Europe, dry docks, wet docks, arched bridges and other important structures, made almost wholly of concrete, are becoming common. At Erie Basin. Brooklyn, there is a minor, but, so far as it goes, a very satisfactory example of the durability of concrete, in the altars and copings of dry docks in this climate. The upper five altars of the two wooden docks were, as already stated, taken out and rebuilt wholly of concrete, and their condition now, after eighteen years of constant use, is excellent.

The Halifax, Nova Scotia, dry dock, of 580 ft. length, built in 1886 to 1889, is all of concrete, except the meeting faces of the caisson gate, the coping courses of the altars and main walls, and the stairways and material slides, which are of granite, and the linings of the culverts, which are of brick. The inverts of the entrance are all of concrete except the meeting faces. The example, though not wholly satisfactory as to the durability of the concrete, is a very instructive one. Considerable areas of the inner surface of the body walls have scaled off, and have been relined with blue bricks, but the failure is readily accounted for by much of the walls having been built under most unfavorable conditions as to storms and frost, and storage of cement. On the other hand, adjoining parts of the main walls, and all of the inverts and walls of the entrance, are standing excellently well. Altogether, the dock shows that really good concrete is a proper material for dock walls, even in a rigorous climate.

A notable example of a very large dry dock, with walls almost wholly of concrete, is the new No. 3 Graving Dock at Glasgow, designed by Mr. Deas, Engineer of the Clyde Trust. It is 880 ft. long, 115 ft. wide at top, 32 ft. depth from floor to coping, and is divided into two sections by gates. The side walls are entirely of concrete, except a thin backing of brickwork placed against the sheet piling which surrounds the walls. A peculiar and what appears to be an excellent method of construction of the walls is that their whole inner faces are made, not out of concrete built *in situ*, but of granolithic concrete blocks, separately molded and hardened, and then built into place as ashlar. The altars, up to about half the height of the walls,

Mr. Kennedy.

are 3 ft. 6 ins. high and 20 ins. tread, and from that to the top of the walls are 18 ins. high by 14 ins. tread, the granolithic blocks being molded to the height of the altars in each case, so that a course of blocks builds an altar. The coping of the top of the walls is also of granolithic blocks. The head of the dock is semi-circular, without altars, and is lined with concrete blocks which are of heights corresponding to the adjoining altar courses, but these blocks, not having exposed tops, are made of ordinary concrete with only a granolithic facing 3 ins. in thickness. The cost of the dock and its accessories, all complete, including everything except the purchase of land, was £237 000 = $1 153 400, which is remarkably low for a double dock of such large dimensions.

An older example of a concrete dry dock in Britain is that at Newport, completed in 1890, of 350 ft. length by 30½ ft. depth, and, although built on a very difficult site, its cost was only $121 500.

An important example of concrete construction, for purposes analogous to those of dry docks and exposed to somewhat severe weather conditions, is that of the locks of the Trent Canal in Ontario, now being built by the Government of Canada.

The advantages in strength, durability and economy of maintenance of dry docks of stone, and of stone and concrete, over those of wood, have been ably and fully shown in the discussions presented; and, for the reasons just outlined, the speaker adds a plea for dry docks built almost wholly of concrete, as possessing much of the advantages of both.

Mr. Ritchie.

JAMES RITCHIE, M. Am. Soc. C. E.—The speaker built a dry dock recently, but it was of wood, as is customary on the lakes. He suggested that the abutments be built of stone, but the cost of such work was the objection made by the owners, and only a small amount of concrete was used. It is a large dock, 560 ft. long and 100 ft. wide, but, as has been stated, it has the one advantage of a wooden dry dock—it is shallow, only 17 ft. on the sills; consequently it is considered perfectly safe, and has so far been extremely satisfactory. For a dock of great depth, or for docks where the first cost is not the essential matter, stone, or concrete lined with stone, is, in the speaker's opinion, the only proper material to use.

Mr. Collingwood.

FRANCIS COLLINGWOOD, M. Am. Soc. C. E. (by letter).—The original cost of wood construction is, of course, less than stone. The repairs and renewals are a matter of experience, and it is claimed by those having long experience with wooden docks, that the interest on the difference in cost between them and stone will more than pay for keeping the former in first-class condition. The reduced rate of interest now prevailing, however, may cause a change in this regard.

As to convenience, etc., those who are constantly using docks are most competent to speak. Such matters as length of shores and con-

venience in adjusting them, convenience in handling material and, in movements of men, slipperiness and cold to the feet, contents to be pumped out, and other practical matters have to be considered. As the writer's connection has been with construction only, others can speak with more authority. Mr. Collingwood.

It is to be regretted that the experience in building some of the recent timber dry docks has in a measure thrown discredit upon them. Errors in judgment in engineering matters are not justly chargeable against a system of construction which has certainly proved successful in many existing examples.

CHARLES H. HASWELL, M. Am. Soc. C. E. (by letter).—The writer thinks it is to be regretted that the subject under discussion is confined to the relative fitness of the material of a dry dock, inasmuch as piers and bulkheads, erroneously termed docks, are of more general requirements and consequent utility than docks either wet or dry. Custom and some lexicographers term the enclosed space between two piers a dock, whereas it is strictly a basin, although colloquially, whether the structure is a single pier or a bulkhead, it is termed a dock. Mr. Haswell.

If the subject had included piers and bulkheads, whether of masonry, crib-work or rip-rap, the writer would avail himself of the opportunity to refer to their design and construction, on the basis of his experience and observation; but as the subject is confined to the question of the relative merits of stone and wood for the construction of dry docks, it is a restricted one, as it embraces only the relative cost and endurance of such structures.

If the period of construction and the first cost are controlling elements, wood alone can be entertained, as it involves less cost of material and labor in construction, not only in its walls, but in its foundation. Its defective elements are decay and damage by fire, involving the probable damage or destruction of a vessel under repairs.

If, on the other hand, the period of its construction and its first cost are not restricting elements, and a permanent structure is required, stone or concrete is not only indispensable, but, in the matter of ultimate cost, it is questionable if frequent repairs, and the periodic renewal of a wooden structure, would not involve a greater cost than stone.

FRANCIS T. BOWLES, Esq.* (by letter).—After thirteen consecutive years' experience in the active use of wooden and stone dry docks at the Navy Yards at Norfolk, Va., and New York, and after having had sole charge of the repairs to the wooden dry dock, known as No. 3, at the latter place, in which it was necessary to reconstruct the whole entrance, the writer wishes to express an unqualified preference for a Mr. Bowles.

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Mr. Bowles. masonry or concrete dry dock over wooden construction. In testifying before a Congressional Committee about a year ago, the writer expressed the following opinion:

"I believe that a wooden dry dock bears the same relation to a stone dry dock or concrete dock, that a wooden trestle or a wooden bridge bears to a steel bridge or stone culvert. I consider it a temporary structure."

This opinion appears to present the case fairly.

The wooden dry docks built 10 or 12 years ago for the Navy have served their purpose well; they were cheap, and admitted of easy and rapid construction by unlearned persons. They were built at a time when little attention was given to the subject of dock construction in this country, and when materials for stone and concrete work were very expensive. Moreover, these docks supplied an immediate and pressing need which at the time could not have been otherwise met. It is now known that the deterioration which they have developed and the essentially temporary character of the work and material of their construction, show that their continued use involves danger and great expense for repairs.

Consideration of the most elementary principles of engineering leads to preference for permanent rather than temporary construction where cost is not prohibitive, and at the present time the cost of concrete and stone construction is sufficiently low to require of the Government the most durable, safe and best construction of its dry docks.

This opinion is not derived from the recent bids on the new dock at Boston, which, to the writer, appear to be inconclusive. He is strongly opposed to the letting of contracts for the building of a whole dry dock to one person or corporation, on the ground that the nature of the undertaking involves too many undetermined elements to enable any person to make a bid which will enable him to do the best work throughout. The work should be under the sole charge of a competent engineer, who should control absolutely the conduct of the work, and let contracts from time to time for definite portions, on which clear and definite specifications can be made. That is good business, and in the end will produce the best results. This digression from the main subject will possibly be pardoned, because, in advocating stone or concrete docks, it is the writer's opinion that the engineering problems are great, and must be treated by modern methods.

Mr. Boller. ALFRED P. BOLLER, M. Am. Soc. C. E. (by letter).—It is astonishing that a controversy regarding the relative merits of stone and wooden dry docks should be given serious consideration by a great government like that of the United States. That such a controversy does exist is a sad commentary on the intelligence of the source of ultimate power, the National Congress. There are some questions that have only one side, and this is one of them. It is so thoroughly one-sided that only the crass selfishness of interested parties, operating in some mysteri-

ous way upon Congress, forces a consideration of the subject at all. Is there another civilized government under the sun that would thrust aside the united demands, yes, pleadings, of its technical experts to do the right thing, simply for the sake of maintaining a special private interest, whose business is building wooden docks? Mr. Boller.

Stone or wooden docks! As well ask our railways to build wood instead of stone or steel bridges. The only so-called arguments advanced for wooden dry docks are those of economy and expeditious construction. Economy of first cost is one thing, and economy of endurance and maintenance is another. Rapidity of construction is a matter of little importance for a Government work, compared to solidity and endurance, but modern methods of executing work permit of such rapidity of performance that almost any reasonable expectation of time can be met. What if it does take twice as much time to build a stone dock as a wooden one; when the work is done it is done for all time practically, and it can be operated with absolute confidence and freedom from the anxiety that always attends a wooden dock. Absolute safety and economy of endurance are the cardinal requirements for any dry dock suitable for the purposes of a modern navy, with its deep-draught battleships, which can only be met by using imperishable material. To build such docks of wood, that commence to depreciate from the day of their completion, deteriorating increasingly with the years, until absolutely worthless, is serious folly that is belittling to our naval administration, a waste of the public funds, and a source of ridicule with competitive nations. A wooden dry dock is all well enough for temporary purposes, or to meet the necessities of an impoverished government, or the financial limitations of a private party. The United States is in no such impecunious position, and is expanding into a naval power, the limits of which no man can foresee. This country is destined to a restoration of a merchant marine that will recreate the long-lost glory of the seas, now only a reminiscence, and on a scale commensurate with the activities of a hundred million of people, backed with unlimited resources. For the Government of such a nation to even talk of building wooden dry docks, is preposterous. While it is gratifying to know that the comparative cost between the two systems of docks shows, perhaps, 25% difference (according to recent tenders), the question of first cost, to the writer's mind, cuts no figure at all. The United States cannot afford to build wooden docks, even on a simple financial comparison, as the statistics so elaborately discussed by the naval speakers, demonstrate beyond cavil. Whether stone dry docks cost much or little, whether they take twice as long to build as wooden ones or not, there is but one thing for the United States Government to do, and that is to build stone docks, even at the risk of hurting the feelings of existing wooden dry dock companies.

Mr. Mohun. EDWARD MOHUN, M. Am. Soc. C. E. (by letter).—The writer is thoroughly in accord with those who hold, that while a commercial company, or private individual, may be justified, from financial considerations, in the use of timber for these works, yet that a great and wealthy maritime nation would be ill advised if, through the parsimony of its rulers, other than the best and most enduring material were made use of in constructions on which in time of war the efficiency and possibly the very existence of its fleet might depend.

The dry dock at Esquimalt, B. C., was opened in July, 1887; H. M. S. *Cormorant* being the first to enter.

Its dimensions are: Length of floor, 450 ft., which can be increased to 481 ft., by berthing the caisson at the outer invert; breadth of entrance, 65 ft.; breadth at coping, 90 ft.; breadth of floor, 41 ft.; depth on sill at ordinary high water, 26½ ft., and at high spring tides from 29 to 30 ft.

The body of the dock is constructed of concrete faced with masonry.

From the bills of quantities there were used in its construction: 30 639 cu. yds. of concrete, 6 556 cu. yds. of brickwork, and 109 887 cu. ft. of masonry.

Its cost was about $900 000.

It has been in almost constant use for nearly 12 years, and the writer is informed by the Dock Master that the repairs to the body of the dock, during that period, have been effected at the cost of five barrels of cement and a week's wages to a mason.

During the last years the cost of replacing defective work on the caisson chamber and pump wells has been about $4 000. Owing to the records having been destroyed by fire, it is impossible to give the correct figures. Much of this expenditure appears to have been caused by the use of brickwork in the pump wells and entrance works. The writer regrets his inability at the present moment to furnish the actual cost of these repairs, but it appears reasonable to assume that, had the same material been used as in the body of the dock, their cost would have been reduced to a minimum.

The pumps have been furnished with two new sets of rubber valves, and a new pinion and spur wheel have been added to the machinery.

Irrespective of the tendency, of late years, to increase the size of warships, it would seem, that to fulfill all the conditions under which its services might be needed, a dry dock should be long enough to take the longest vessel in the fleet, wide enough at the entrance to take that of the greatest beam, and with depth on the sill to take that of the greatest draught.

The following are the dimensions of the largest ships in the British Navy:

Battle-ships, *Majestic* class: Length, 390 ft.; beam, 75 ft.; draught, 27½ ft. There are nine of this class. Mr. Mohun.

The *Powerful* and the *Terrible* are the two largest cruisers of the British Navy afloat, and have a length of 500 ft., a beam of 71 ft., and a draught of 27 ft.

It appears to the writer that the least dimensions of dry docks for the use of the British Navy at outlying stations would be: Length of floor, 500 ft.; width at entrance, 80 ft., and depth on sill, 30 ft. Probably few engineers would recommend the construction of timber docks of such dimensions to receive battle-ships of 15 000 tons displacement.

A few weeks ago the writer was discussing with the captain of the flagship on this station the size of docks required by the later additions to the British Navy, and that gentleman pointed out that under certain possible conditions a very great depth on the sill might be needed. It must be understood that this was simply in conversation and possibly might not be the result of mature consideration on his part.

For instance, suppose a vessel with her bows stove in and her forward compartments full of water, the result perhaps of a naval action or collision; it is obvious that she would be down by the head possibly 10 ft. more than her normal draught, and to enter the dock would need a great depth on the sill. The officer above referred to suggested that a depth of 40 ft. on the sill might be required in such an emergency.

To the writer this is an entirely new view, on which he does not feel competent to express an opinion.

A case somewhat in point, however, occurred here a few years ago. The second-class cruiser, *Amphion*, 4 300 tons, with a usual draught of 22½ ft., was taken into dock after ripping up her bottom on a rock. She reached the dock at high water, and was just able to enter, grazing the sill.

The Admiralty grant toward the construction of the Esquimalt dock was $250 000, and this single use of the dock probably recouped the amount and possibly saved a vessel to the British Navy.